DESIGN OF THE ELECTRON CYCLOTRON HEATING EXPANSION SYSTEM ON EAST

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1. OVERALL SYSTEM ENGINEERING DESIGN

The EAST Electron Cyclotron Resonance Heating (ECRH) system operates at a frequency of 140 GHz or 105 GHz, utilizing plasma heating by the X2 mode, with currently four subsystems [1]. We plan to upgrade the four ECRH systems to six, enhancing ECRH's power output capability at the 140 GHz frequency point to 3.5~5MW for up to 1000 seconds. To accommodate the entire operational range of EAST's toroidal field, the two additional systems, i.e. #5 and #6 system, will primarily operate at 140 GHz but can switch to a secondary frequency of 105 GHz to adapt to EAST's low toroidal field operations. The layout diagram of the ECH expansion system is shown in the red rectangular area in Fig. 1.

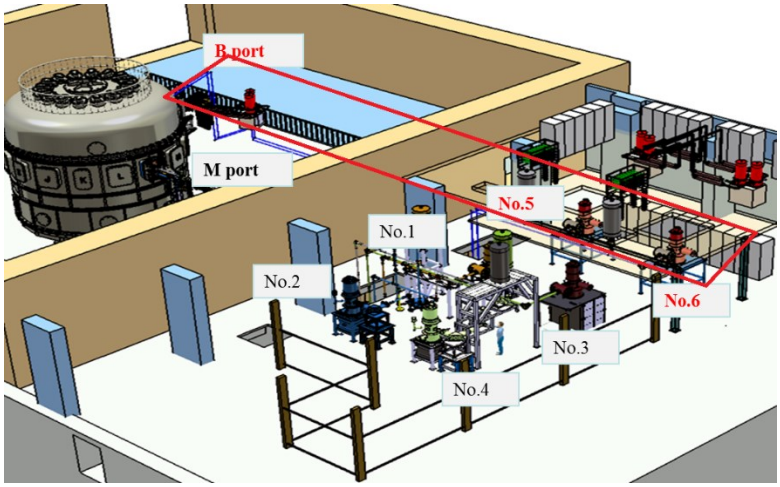

Fig. 1 The layout diagram of the EAST ECRH system, where the extended #5 and #6 systems are in the red rectangular area.

2. TRANSMISSION LINES AND ANTENNA SYSTEM

The EAST [2] facility currently employs four sets of ECRH systems , whose transmission lines adopt corrugated circular waveguides. To maintain system compatibility, the upgraded #5 and #6 systems will also utilize this type of waveguide. The #5 and #6 ECRH system sources are located in Hall 8-1, with antennas positioned at the B window of the EAST device. The transmission channels will follow the existing spatial layout of the 2.45 GHz Lower Hybrid Wave (LHW) system transmission lines. Based on millimeter-wave transmission characteristics and the spatial constraints of the current channels, the optimized design features two parallel transmission lines. Each line undergoes 10 directional changes, and the combined total length of both lines is approximately 150 meters. Each transmission line has a power capacity of 1 MW and operates at frequencies of 140/105 GHz, meeting the requirements for continuous-wave operation.

According to the EAST port layout plan, the upgraded systems #5 and #6 share horizontal Port B with the upgraded 4.6GHz Lower Hybrid Wave (LHW) system. Port sharing reflects EAST’s compact design, necessitating innovative integration of auxiliary heating systems.

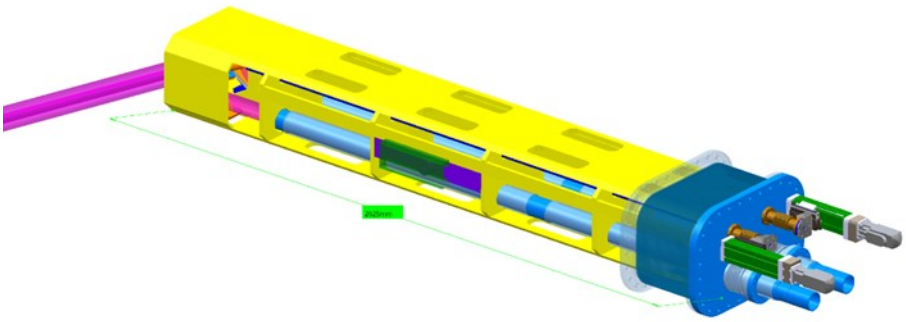

Fig. 2 The antenna for the electron cyclotron heating expansion system.

3. CONTROL SYSTEM

We will develop an independent control system for the #5 and #6 systems, including a new automatic restart control system and a real-time power control system. The real-time power control system is designed to receive power demand signals from the Plasma Control System (PCS) and output the corresponding power to meet the more flexible power requirements of EAST experiments.

A new central timing controller has been designed with three operating modes: system self-check mode, test mode, and EAST experiment mode. In test mode and EAST experiment mode, the automatic restart function can be enabled, allowing the gyrotron to restart automatically in the event of a fault interruption. That ensures rapid recovery of gyrotrons after transient faults to maintain plasma stability.

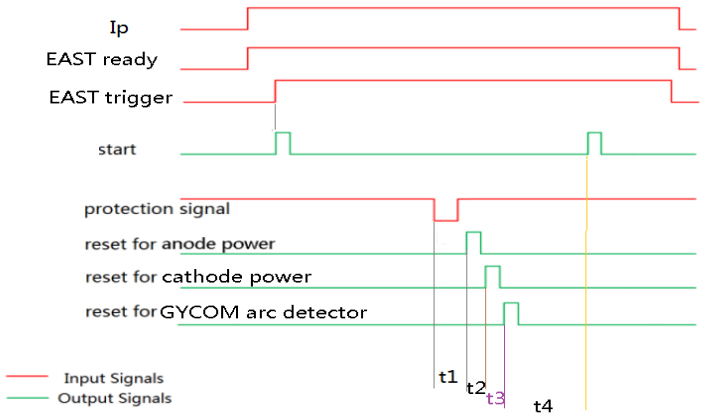

Fig. 3 The automatic restart logic and timing for electron cyclotron heating expansion system (#5 and #6 system).

4. CONCLUSIONS

The expansion design enhances power delivery and frequency modulation to optimize energy deposition into the plasma, addressing challenges such as plasma turbulence and edge-localized modes (ELMs). As part of EAST's advanced heating and current drive (H&CD) systems, the ECH system plays a pivotal role in plasma heating and instability control. Its design focuses on extending operational capabilities to support long-pulse, high-performance plasma experiments, aligning with EAST's goal of steady-state nuclear fusion.

REFERENCES

[1] W. XU et al., Advances and Prospects of ECRH System on EAST, Ieee T Plasma Sci **52** 10 (2024) 5159.
[2] GONG, X., Overview of recent experimental results on the EAST tokamak, Nucl Fusion (2024).